Climate change and uncertainty in the Mid-Atlantic Region

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Coastal Habitat Conservation in a Changing Climate:
Strategies and Tools in the Mid-Atlantic Region
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Quantifying potential coastal impacts

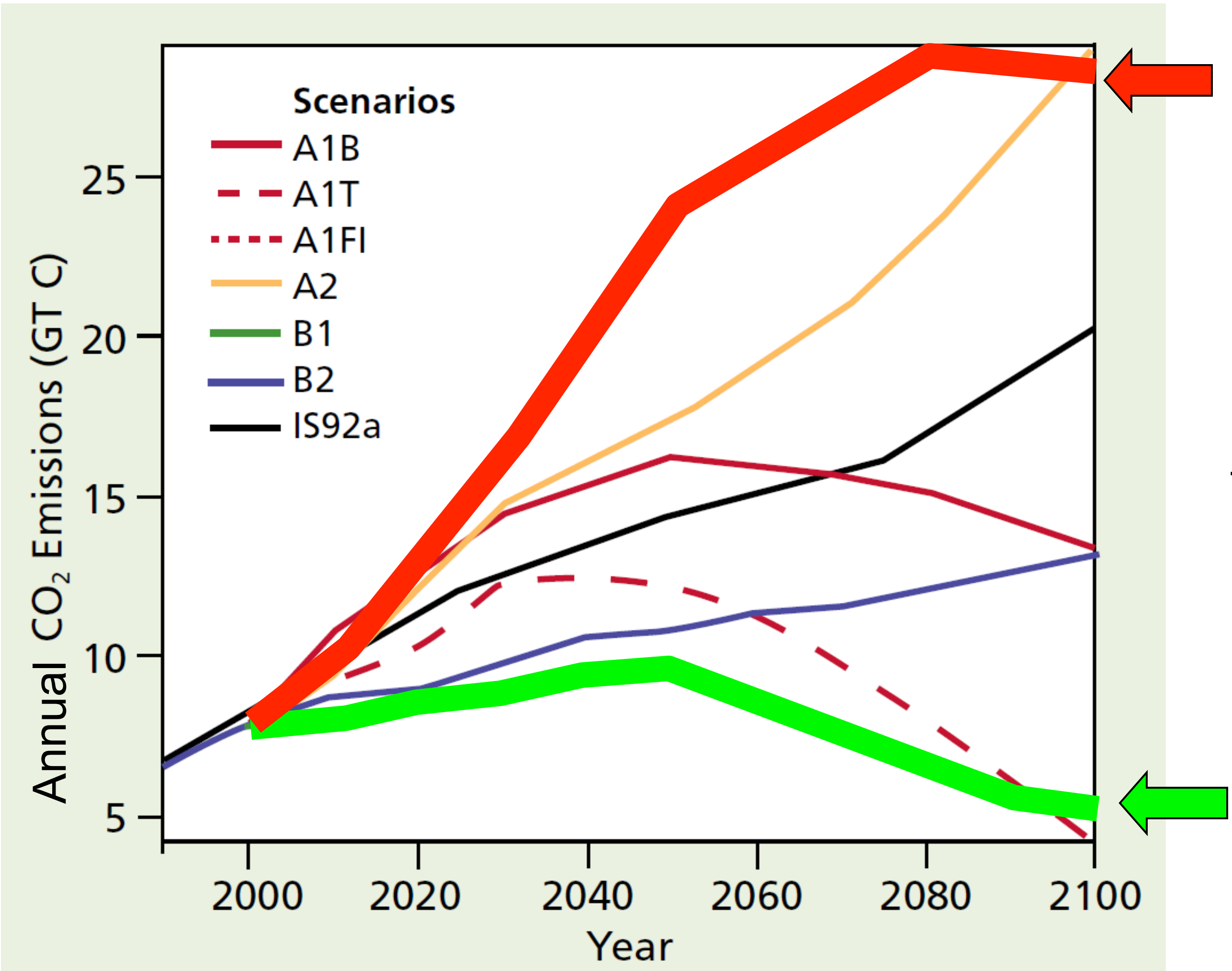
Greenhouse gas emissions → Global climate models → Downscaling temperature, precipitation, winds, sea level etc. → High-resolution hydrological models → Coastal circulation & inundation models

Uncertainty generated during each step!

Outline

- Quick primer on emissions scenarios and Global Climate Models (GCMs)
- The downscaling problem
- What's projected in the Mid-Atlantic Region
- Chesapeake Bay case study

Possible emissions futures



HIGHER

A1FI (940 ppm)

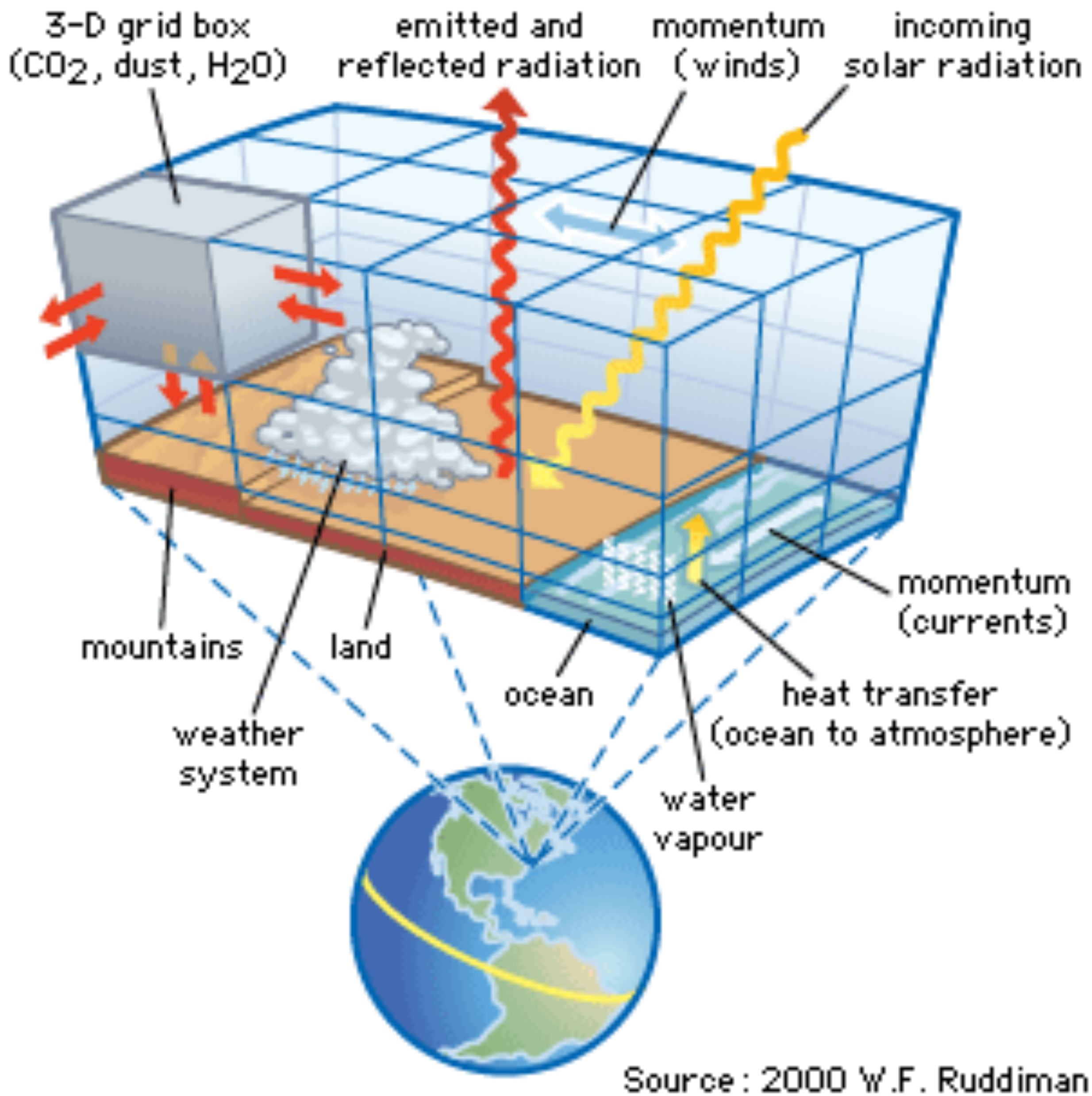
End-of-century CO_2 concentrations range from ~double to triple pre-industrial levels

LOWER

B1 (550 ppm)

Source: Prentice et al. (2001)

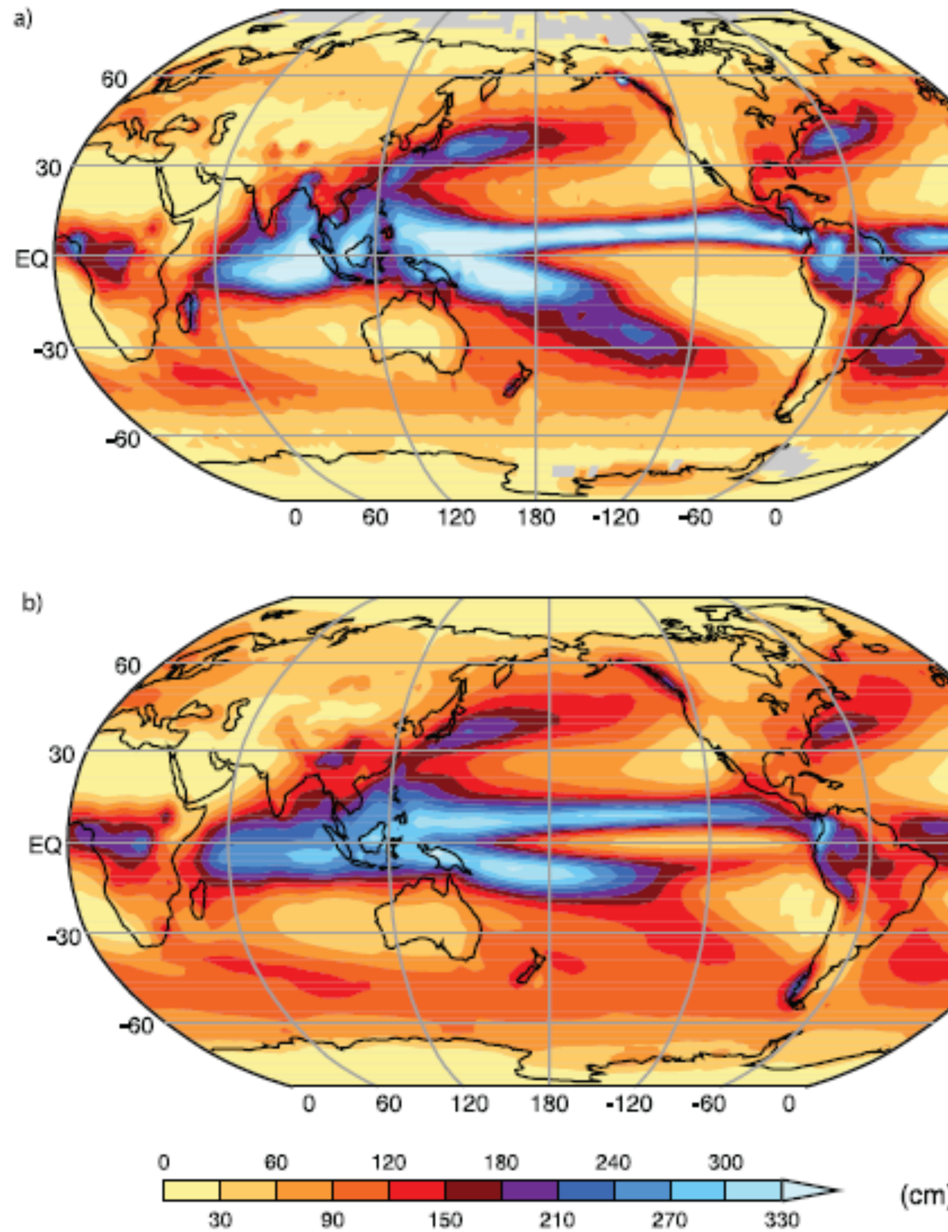
Concept diagram of climate modeling



GCM performance, Annual precipitation

Simulated (multi-model average)

observed



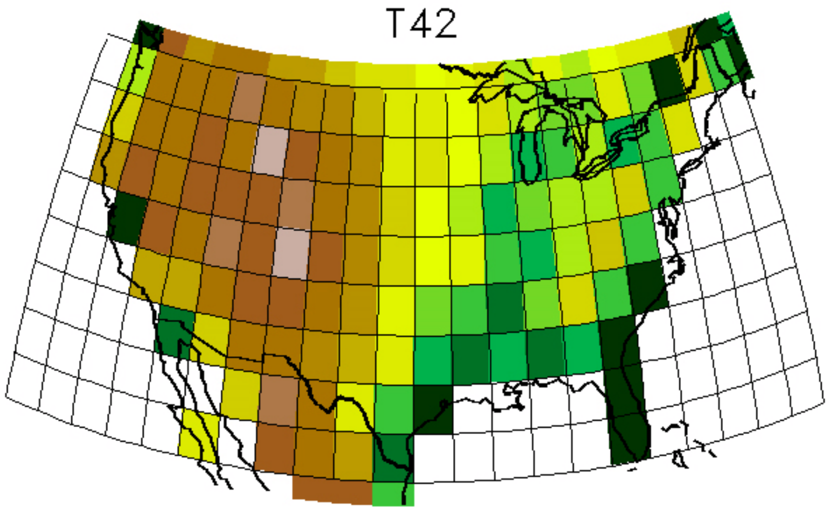
Source: Randall et al. (2007)

A problem of scale

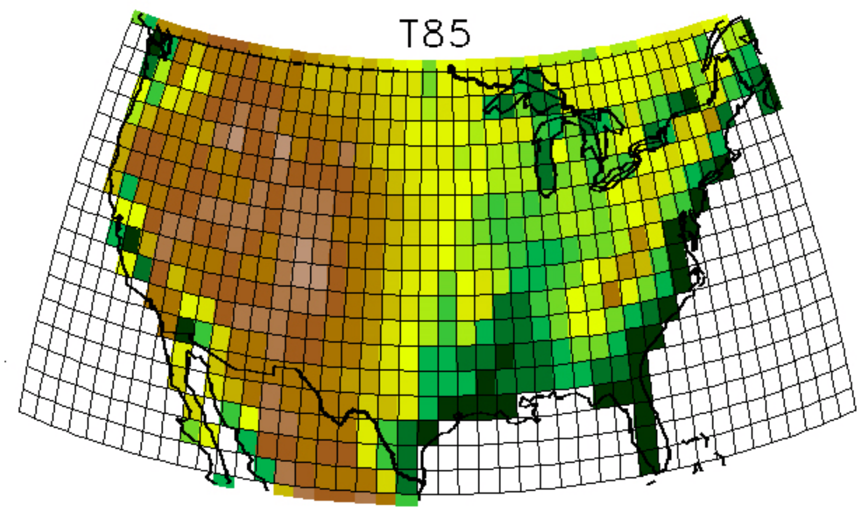
The scale at which you want to predict:

Source: www.katrina.noaa.gov

The scale at which you can predict:



(~3°)



(~1.5°)

Source: www.ucar.edu/news/features/climatechange/images/resolution.jpg

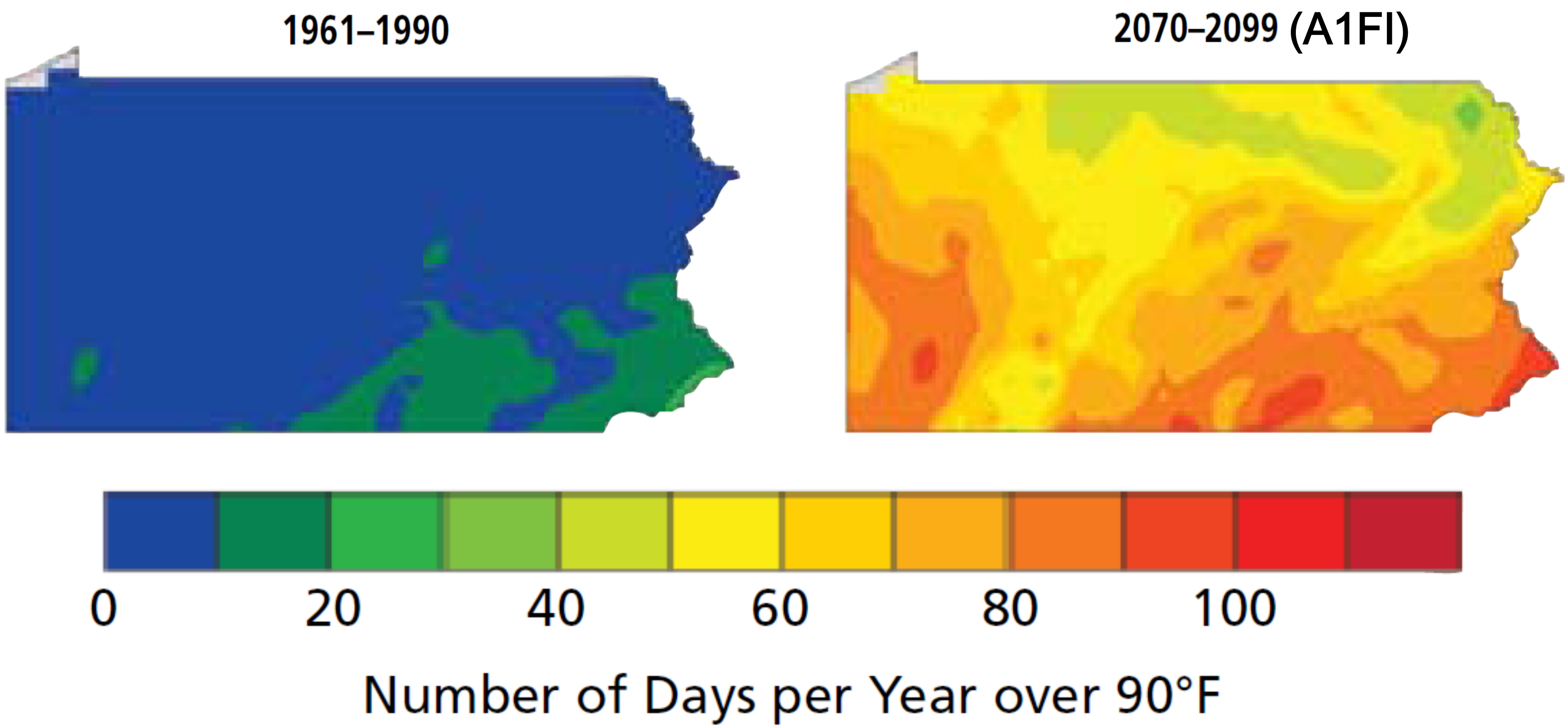
Downscaling

The process of making coarse-resolution global climate model output relevant at the local scales of interest

Two main types of downscaling

- Statistical: Use relationships based on current observations to link large-scale atmospheric and oceanic features to phenomena of interest
- Dynamical: Nest a high-resolution regional climate model (RCM) into a GCM

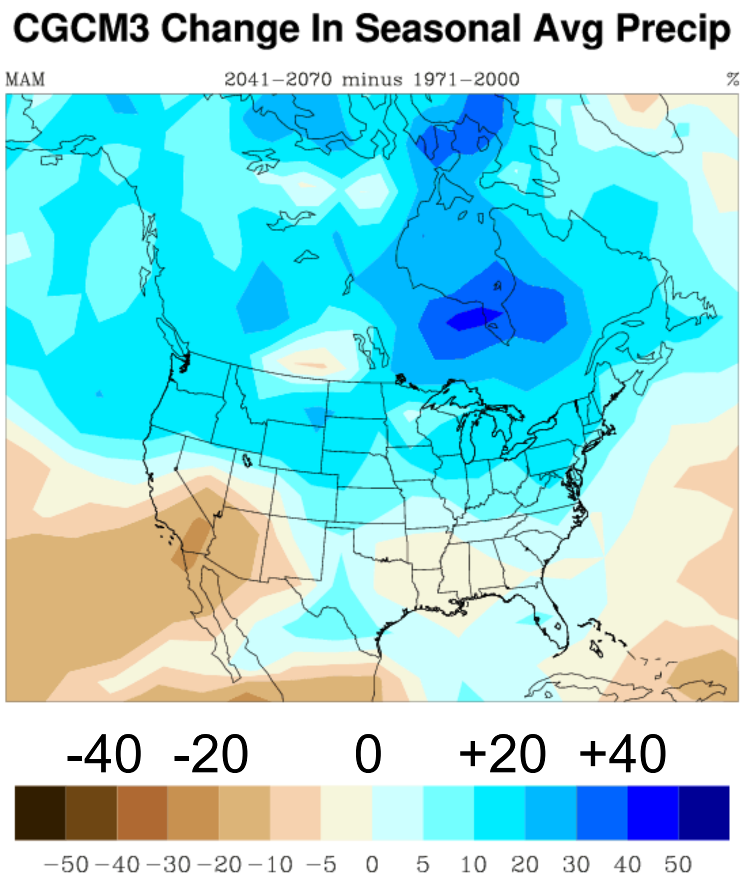
Example of statistical downscaling applied to Pennsylvania



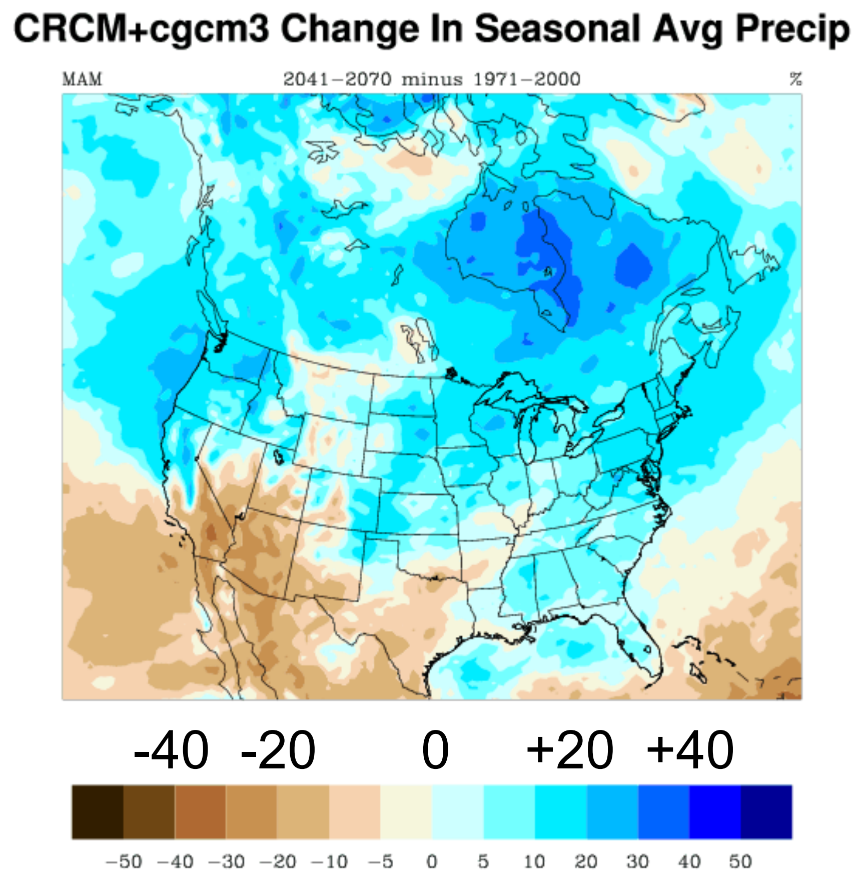
Source: Union of Concerned Scientists (2008)

Dynamical downscaling results: Spring precipitation change (%) by mid-century, A2

Canadian Global Climate Model

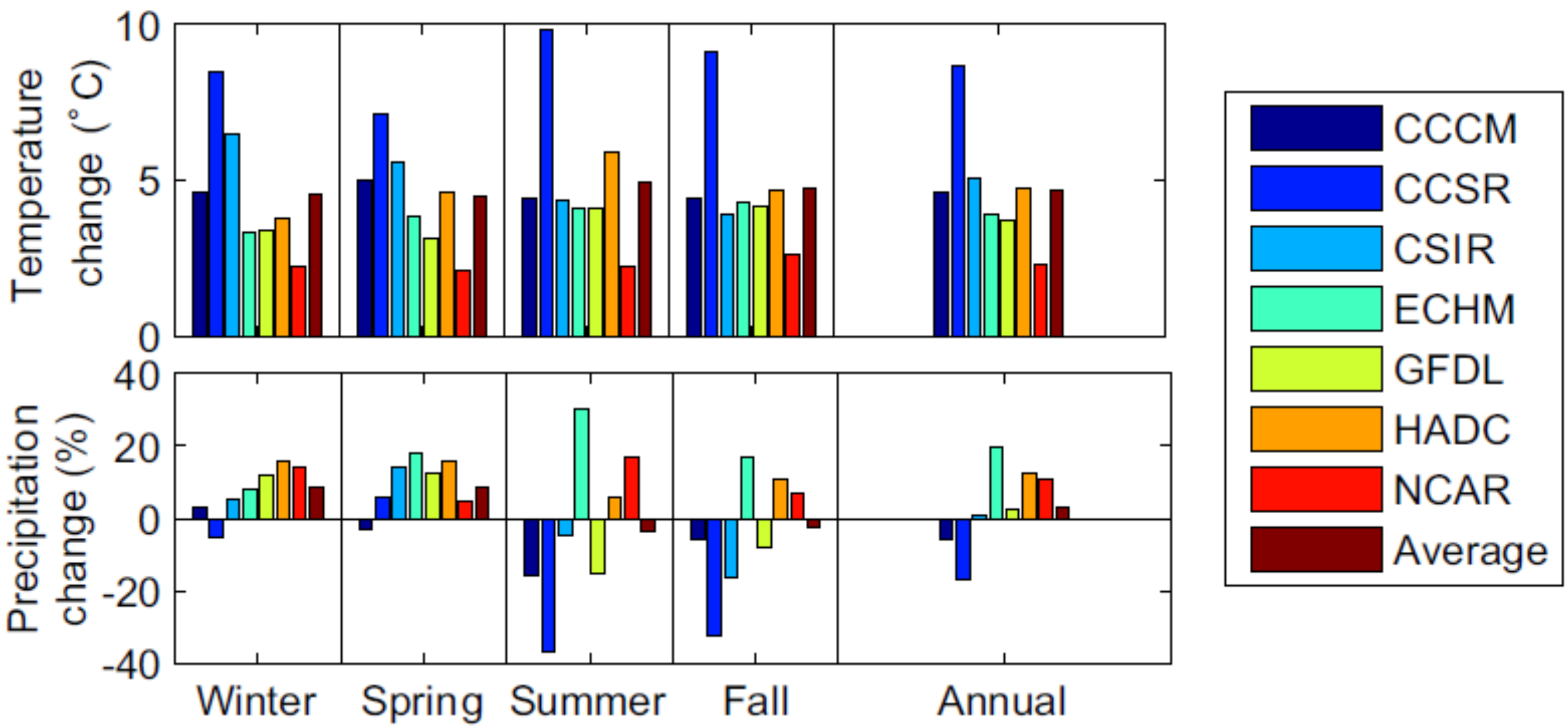


Canadian Regional Climate Model



Source: narccap.ucar.edu

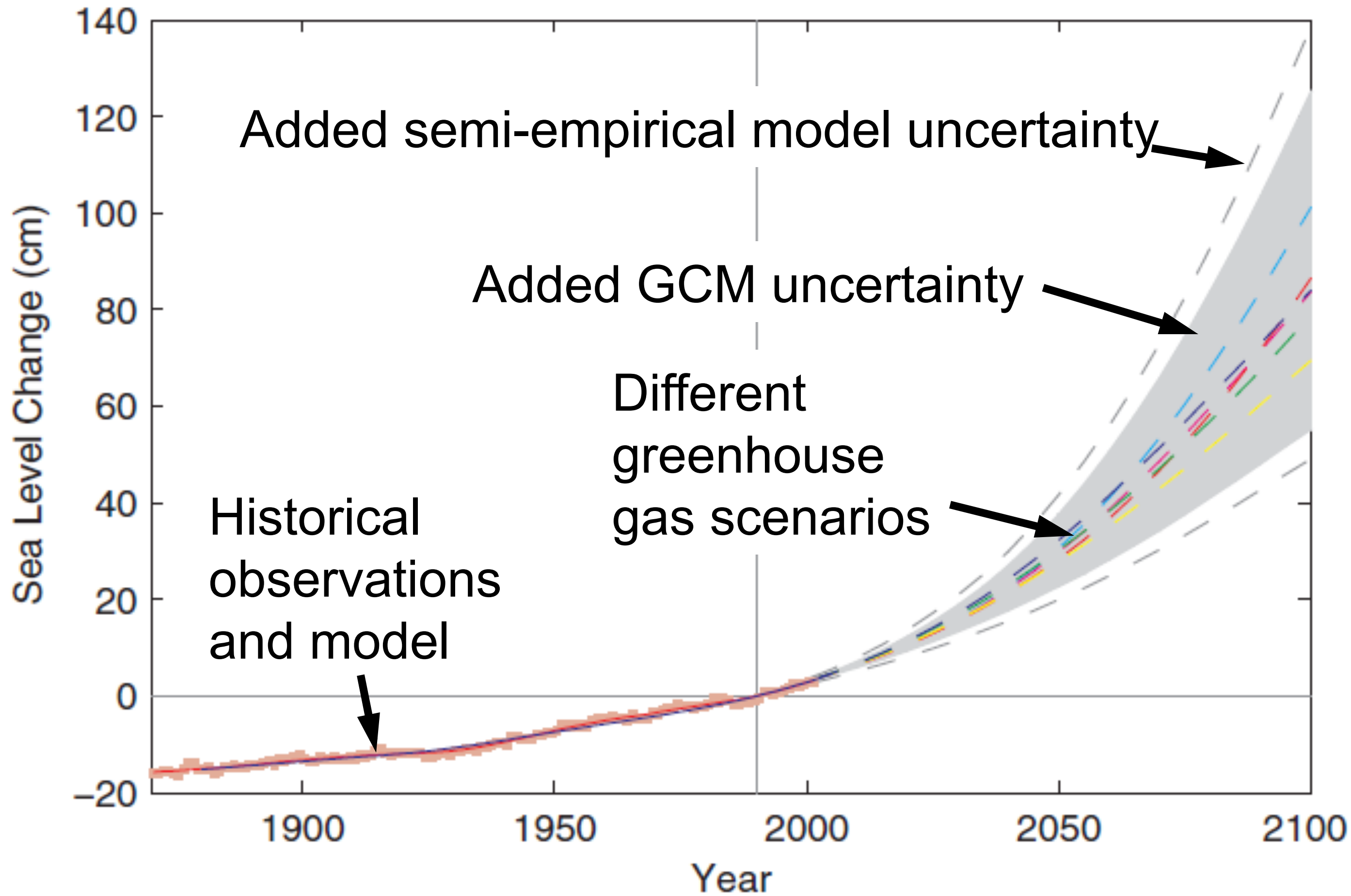
End-of-21st-Century climate projections for Chesapeake Watershed (A2 scenario)



Najjar et al. (2010)

Future global sea level change

Semi-empirical model of global-mean sea level based on global-mean surface air temperature



Source: Rahmstorf (2007)

Downscaling global sea level projections

Local change =	Confidence
global average change	*medium*
+ redistribution effects	*low*
+ local land movement	*high*

Projected Mid-Atlantic Climate Change

Projected change	Likelihood
Warming	Extremely likely
Higher sea levels	Extremely likely
Higher winter and spring precipitation	Very likely
Higher annual precipitation	Likely
Higher winter & spring streamflow	Likely
Greater hydrological extremes	Likely

Sources: Boesch (2008), Christensen et al. (2007), Hayhoe et al. (2007), Najjar et al. (2009), Najjar (2010), Shortle et al. (2009)

Application of climate change projections to the Chesapeake Bay

- Formal, quantitative modeling structure not yet available
- Currently, assessments based on limited literature, expert opinion

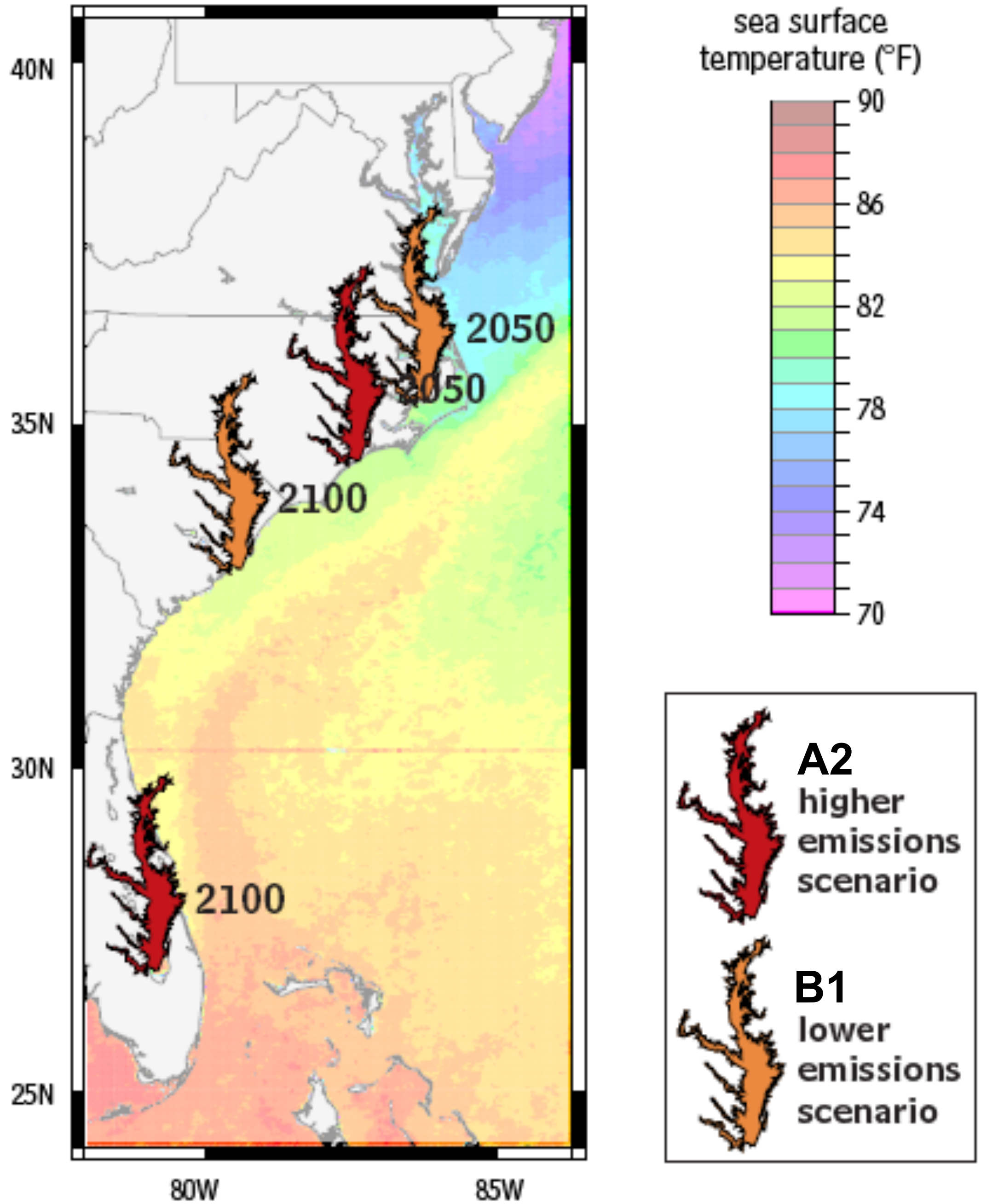
Likely impacts on the Bay

- Increase in submergence of estuarine wetlands
- Increase in salinity variability
- Increase in harmful algae
- Increase in hypoxia
- Reduction of eelgrass
- Substantially altered interactions among trophic levels

Main conclusion: restoration efforts must account for climate change

Source: Najjar et al. (2010)

Moving estuary analogue: summer temperature change



Source: Boesch (2008)

Summary

- Many steps from greenhouse gas emissions to coastal impacts → uncertainty
- GCMs simulate many large-scale atmospheric and oceanic phenomena well
- Downscaling needed to make GCM output locally relevant
- Uncertainty in physical climate projection depends on variable of interest
- Use of coastal circulation, inundation, and ecosystem models for climate impact assessment is in its infancy

Thank you

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Extra slides

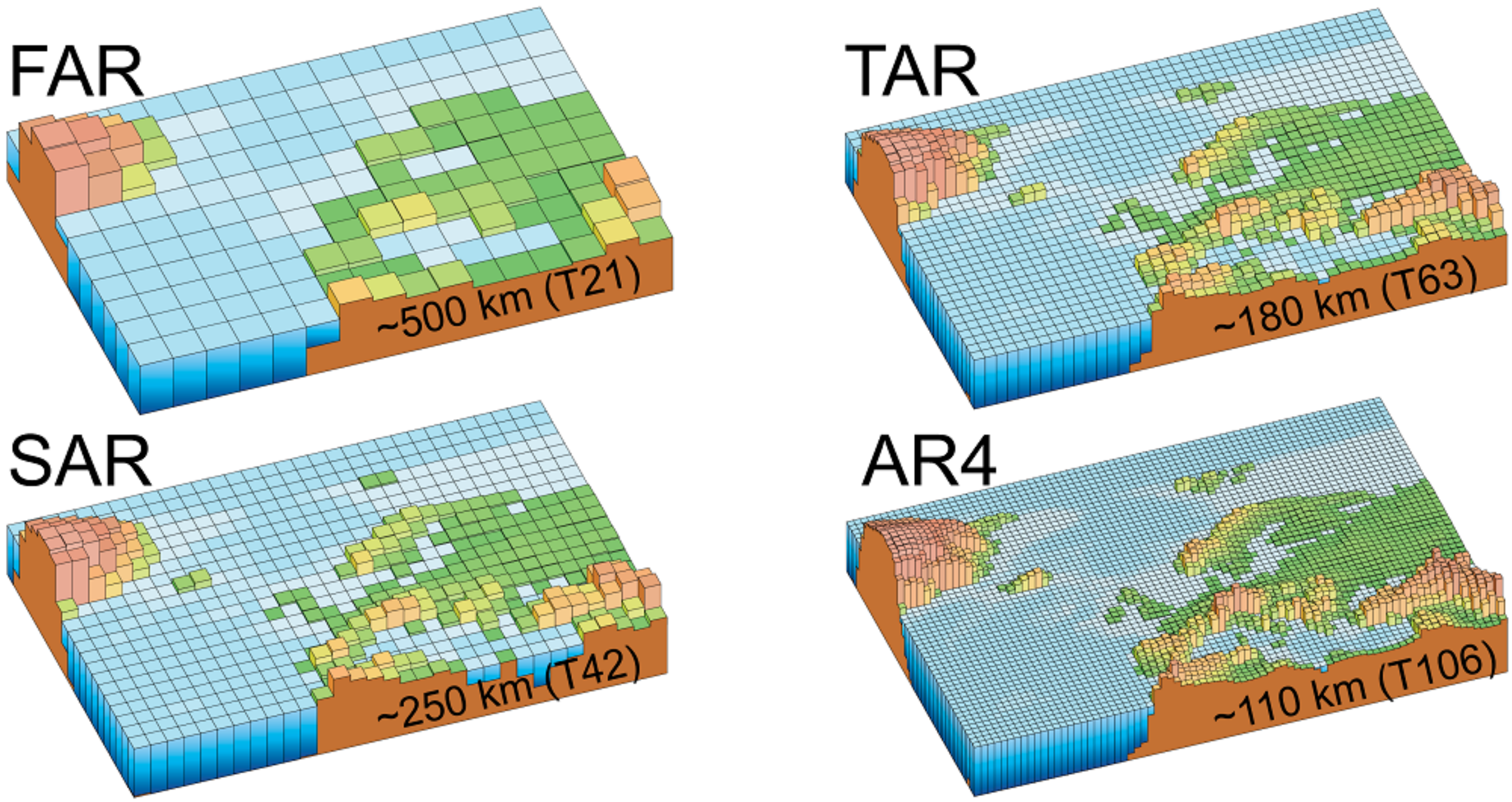


Figure 1.4. *Geographic resolution characteristic of the generations of climate models used in the IPCC Assessment Reports: FAR (IPCC, 1990), SAR (IPCC, 1996), TAR (IPCC, 2001a), and AR4 (2007). The figures above show how successive generations of these global models increasingly resolved northern Europe. These illustrations are representative of the most detailed horizontal resolution used for short-term climate simulations. The century-long simulations cited in IPCC Assessment Reports after the FAR were typically run with the previous generation's resolution. Vertical resolution in both atmosphere and ocean models is not shown, but it has increased comparably with the horizontal resolution, beginning typically with a single-layer slab ocean and ten atmospheric layers in the FAR and progressing to about thirty levels in both atmosphere and ocean.*

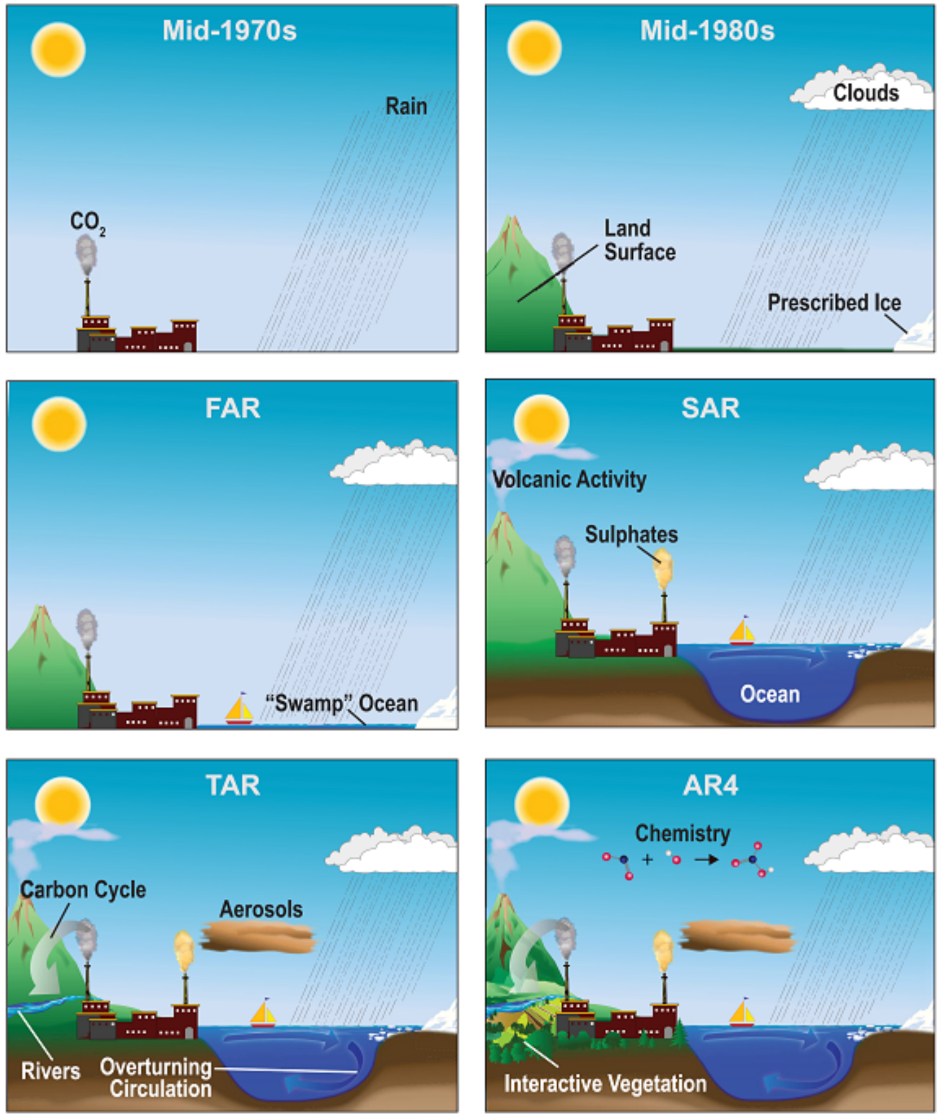
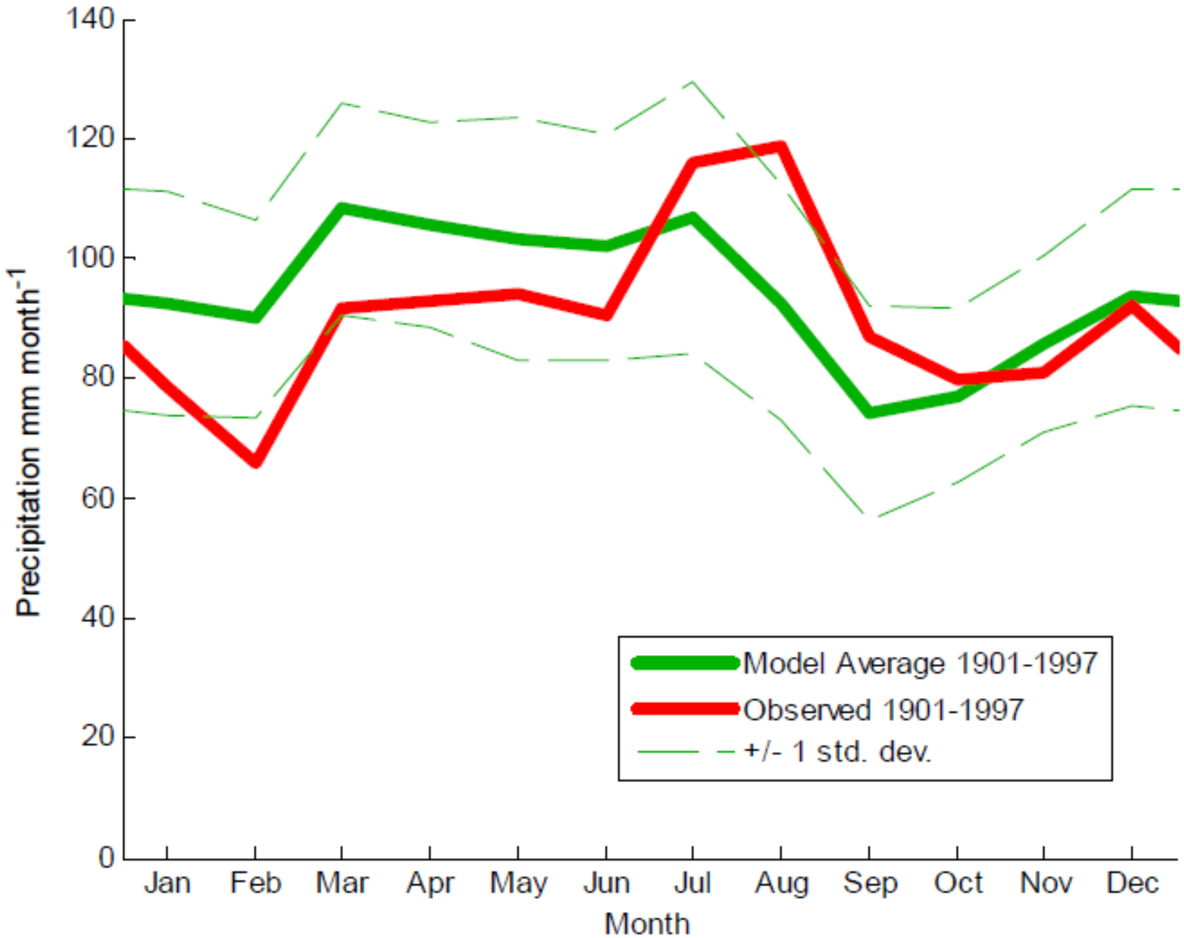


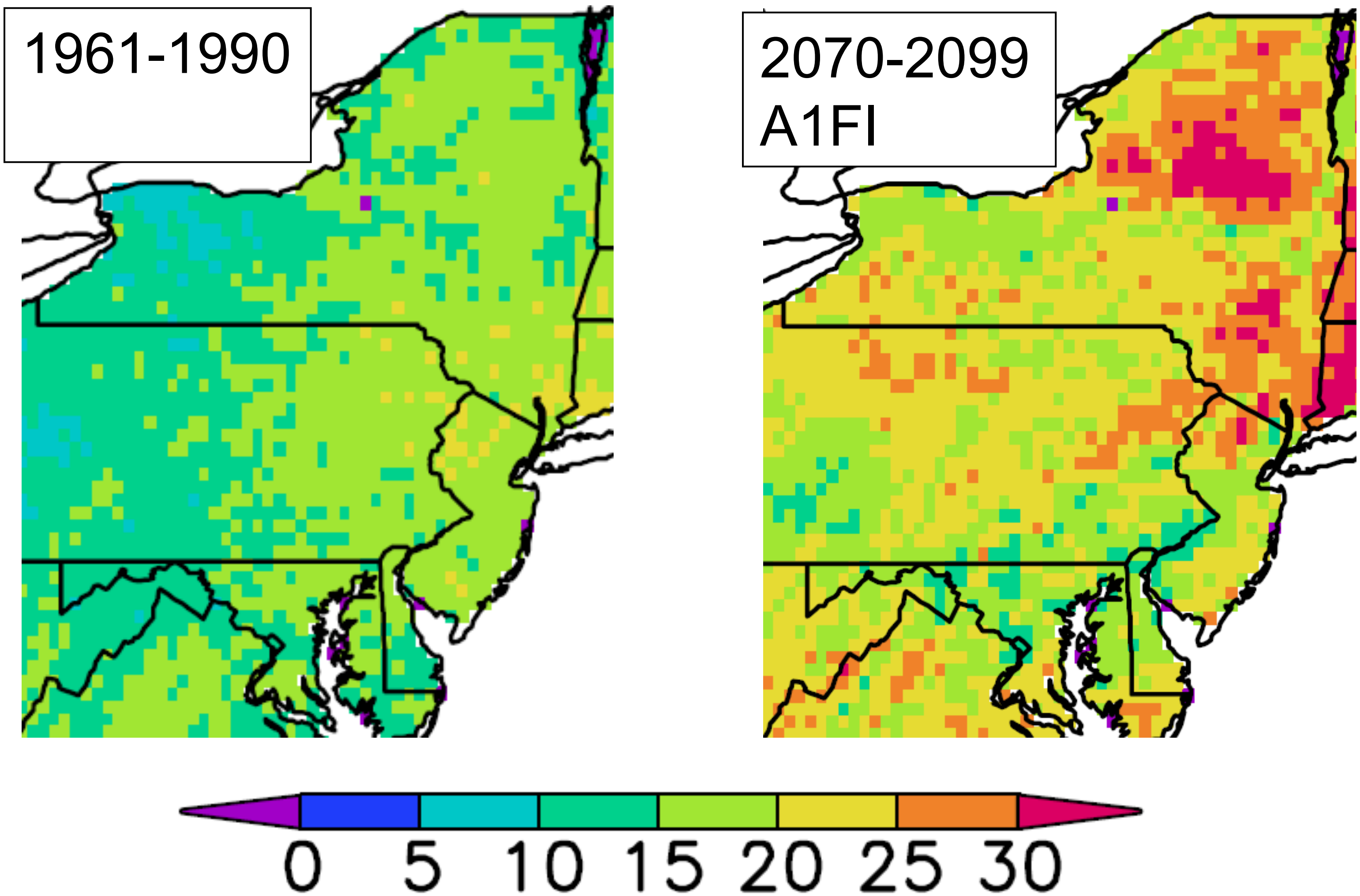
Figure 1.2. *The complexity of climate models has increased over the last few decades. The additional physics incorporated in the models are shown pictorially by the different features of the modelled world.*

Evaluation of GCMs for Delaware Estuary Watershed



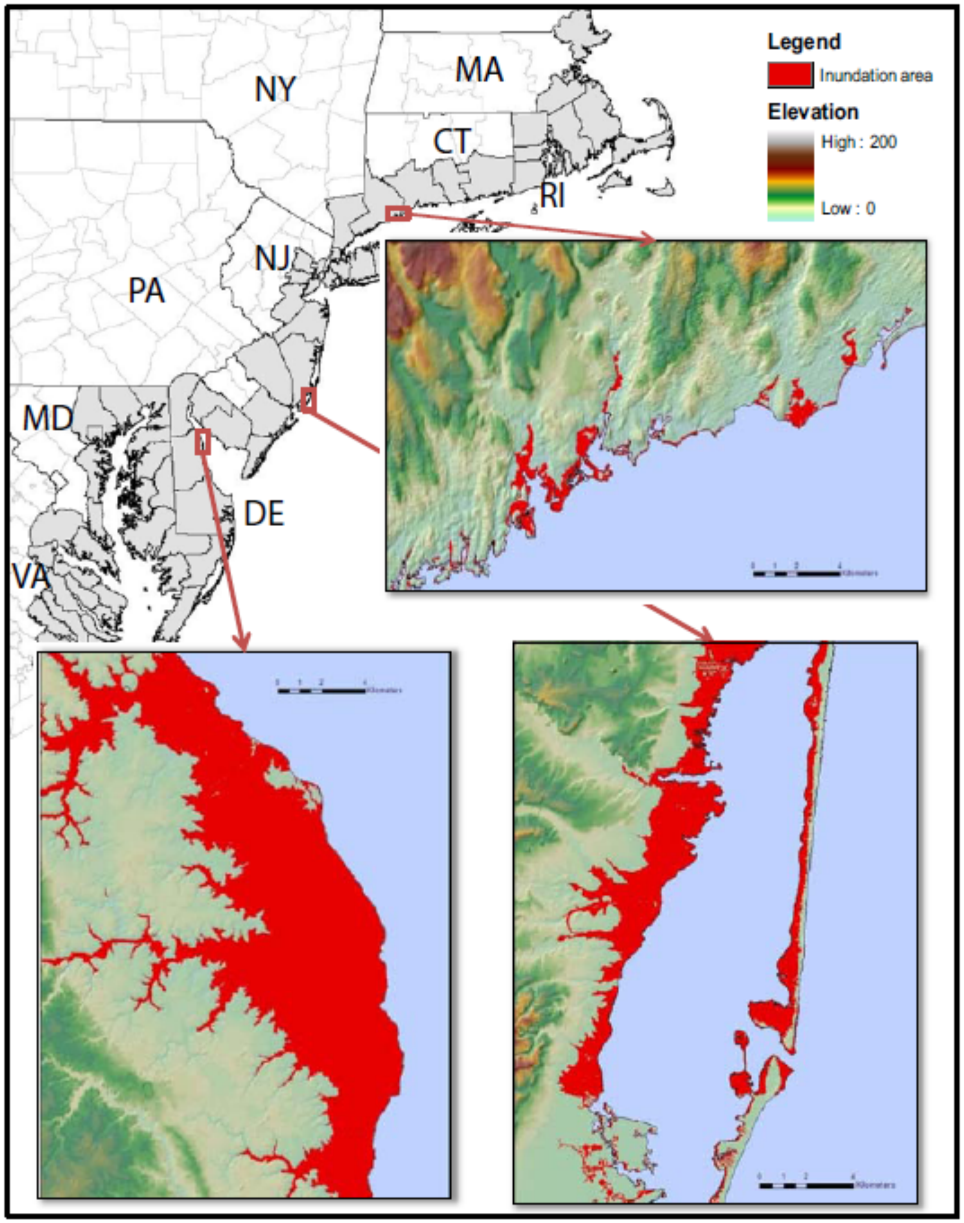
Source: Najjar et al. 2010a

Hydrological example: number of short-term droughts every 30 years



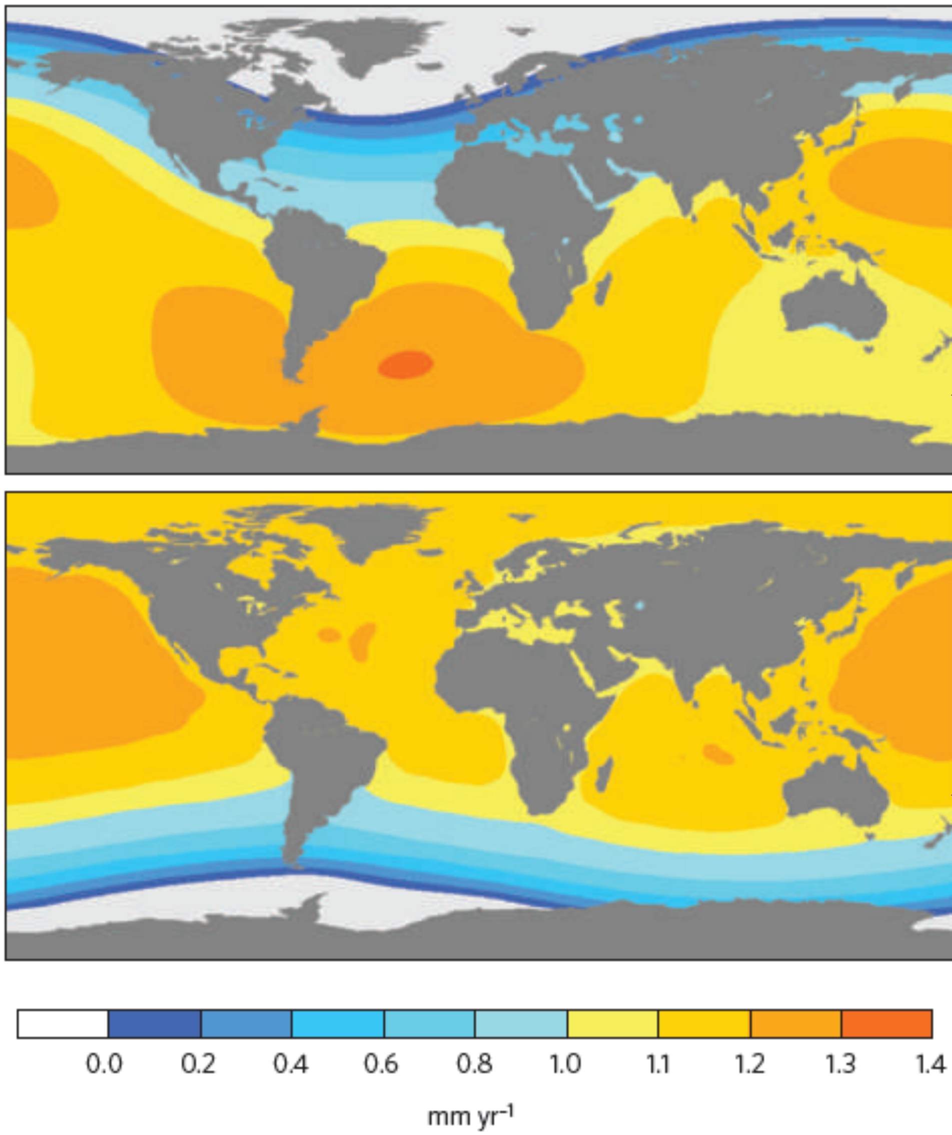
Source: Hayhoe et al. (2007)

Coastal example: inundated regions by 2100, B2 scenario



Source: Wu et al. (2009)

Future regionality due to gravity changes



Sea-level change due to 1-mm yr^{-1} sea-level rise equivalent resulting from melting of:

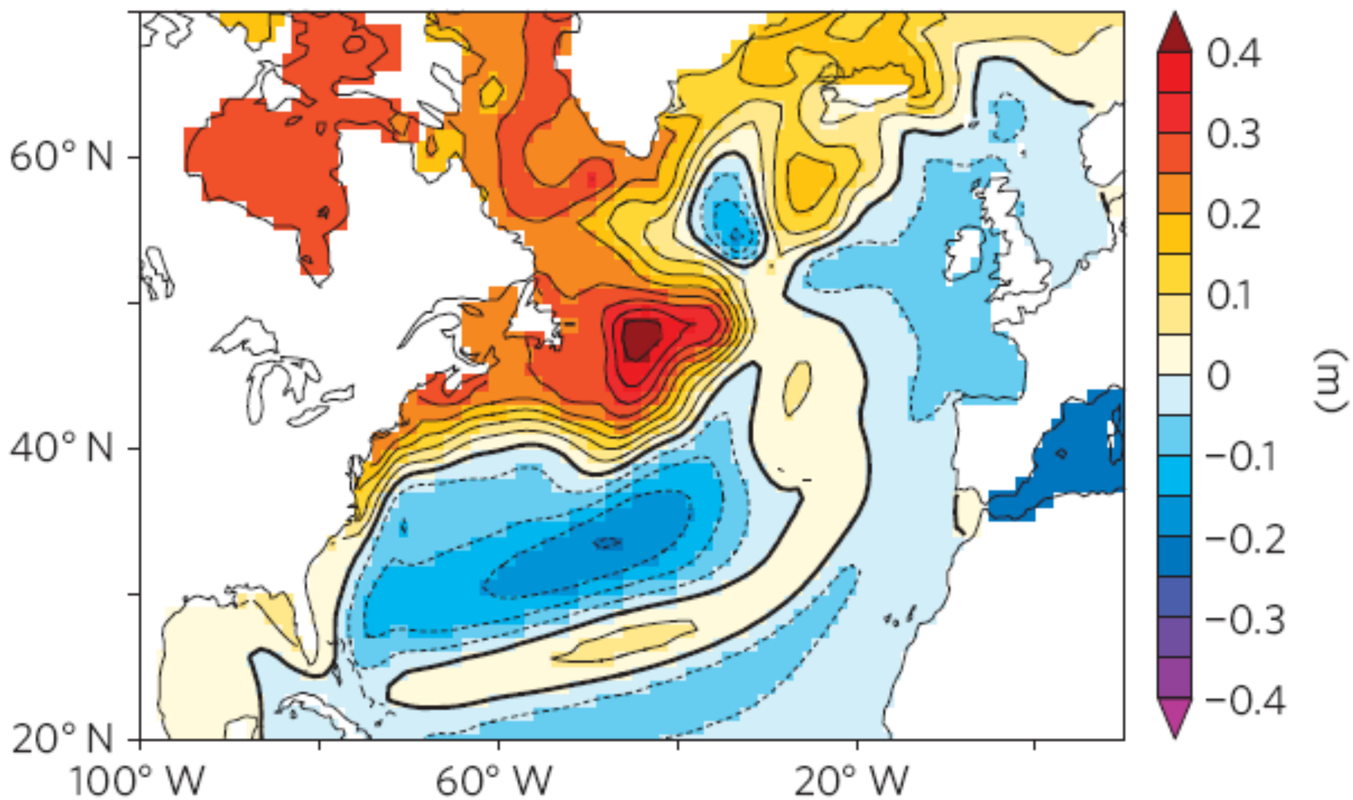
the Greenland Ice Sheet

the W. Antarctic Ice Sheet

Source: Milne et al. (2009)

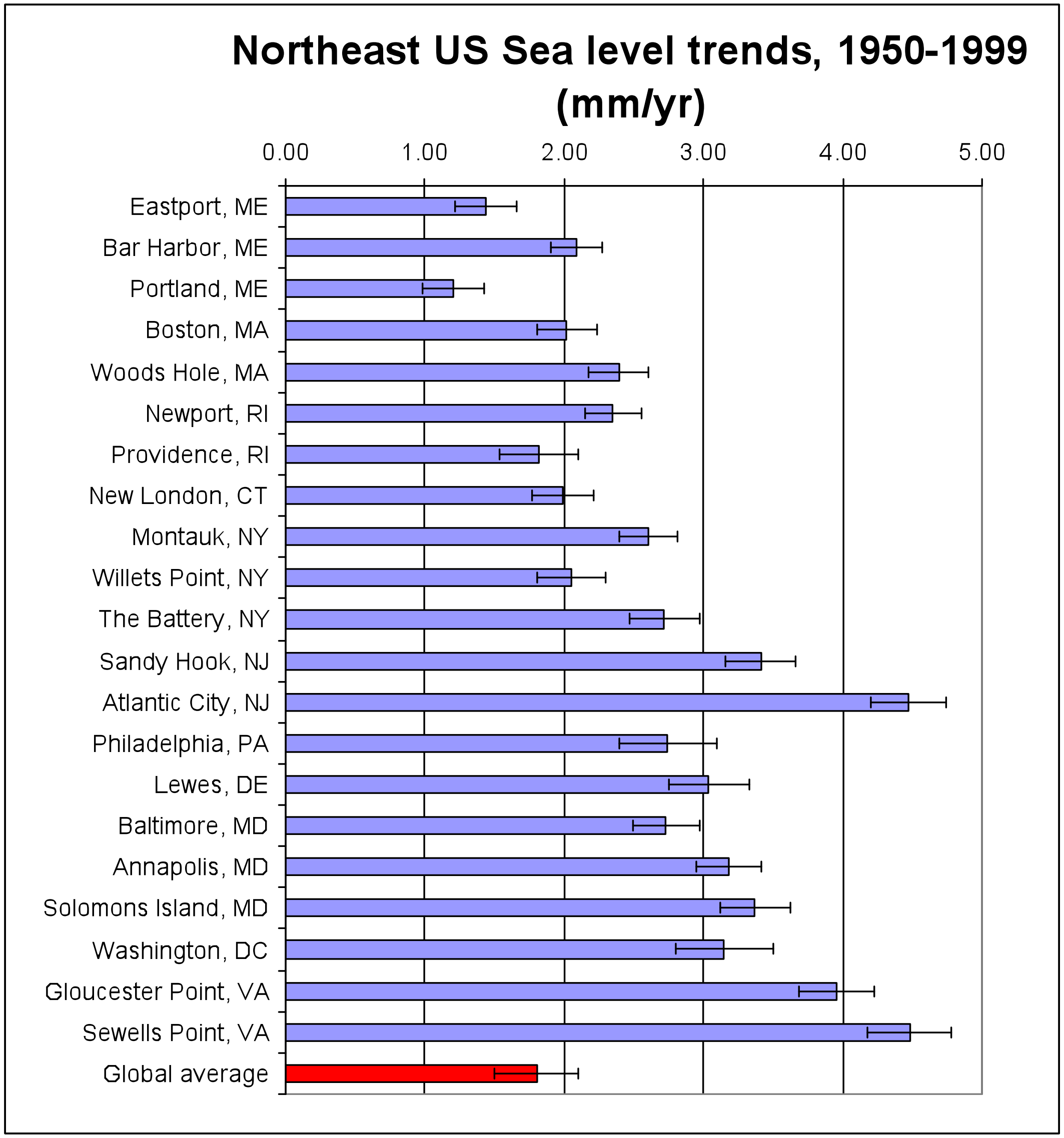
Future regionality due to changing ocean currents

Projected 21st century change in dynamic sea level from the GFDL CM2.1 model (A2 scenario)



Source: Yin et al. (2009)

Regional changes—Northeast U.S.



In the Northeast U.S., sea level is rising much faster than the global average, most likely due to local land subsidence.

Inferred subsidence rates are -0.6 to 2.7 mm yr^{-1}.

Over the 21st Century, this is an additional sea-level rise of -6 to 27 cm.

Sources: Zervas (2001), Church et al. (2004)